Lidar for Lateral Mixing (LATMIX)

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Award Number: N0001411WX21010
http://www.smast.umassd.edu/mixing/lidar_ONR_NSF.php

LONG-TERM GOALS

Our long-term goal is to better understand lateral mixing processes in the ocean on scales of 10 m to 10 km, i.e., the "submesoscale". We aim to understand the underlying mechanisms and forcing, as well as the temporal, spatial, and scale variability of such mixing. The research will contribute to fundamental knowledge of ocean dynamics at these scales, and to efforts to properly parameterize sub-grid scale mixing and stirring in numerical models. Ultimately our research will also enhance modeling and understanding of upper ocean ecosystems, since the flow of nutrients and plankton depends on stirring and mixing at these scales.

OBJECTIVES

One objective of our work is to determine the extent to which shear dispersion – the interaction of vertical mixing with vertical shear – can explain lateral dispersion at scales of 10 m to 10 km. A second objective is to determine whether slow but persistent vortices enhance the stirring attributable to shear dispersion. We also share the overall objectives of the Lateral Mixing DRI to try to determine the extent to which submesoscale stirring is driven by a cascade of energy down (in wavelength) from the mesoscale versus a propagation of energy upwards from small mixing events (e.g. via generation of vortices). A key technical goal of our work is to develop the use of airborne LIDAR surveys of evolving dye experiments as a tool for studying submesoscale lateral dispersion.

This annual report marks the end of year 3 of a 5 year study as part of the "Scalable Lateral Mixing and Coherent Turbulence" (a.k.a., LatMix) DRI. The main effort of the present work is a collaboration between J. Ledwell and E. Terray (WHOI), M. Sundermeyer (UMass Dartmouth), and B. Concannon (NAVAIR).

This project is being performed jointly with a collaborative NSF grant to J. Ledwell, E. Terray, and M. Sundermeyer (see "Related Projects" below). ONR is providing support for the airborne LIDAR operations and for some of the field operations and analysis.

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **30 SEP 2011**	2. REPORT TYPE	3. DATES COVERED **00-00-2011 to 00-00-2011**
4. TITLE AND SUBTITLE **Lidar for Lateral Mixing (LATMIX)**		5a. CONTRACT NUMBER
		5b. GRANT NUMBER
		5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)		5d. PROJECT NUMBER
		5e. TASK NUMBER
		5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **NAVAIR,EO & Special Missions Sensors Division,22347 Cedar Point Road,Patuxent River,MD,20670-1161**		8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)		10. SPONSOR/MONITOR'S ACRONYM(S)
		11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**5**	

APPROACH

Our approach is to release dye patches on an isopycnal surface in the seasonal pycnocline, and to survey their evolution for periods of 1 to 6 days. Drogues released with the dye not only help with tracking but also give valuable measurements of the shear/strain field on the outer scale of the patches. Lagrangian floats released with the dye patches give measurements of shear and strain following the patch (D'Asaro). The dye patches are sampled not only with towed instruments from ships (Sundermeyer; Levine) but also, as mentioned above, with airborne LIDAR (Concannon, Terray, Sundermeyer). Because of the scope of the DRI of which our work is a part, the hydrographic and dynamic setting of the dye dispersion studies have been well measured with profiling towed bodies from two other ships (Lee and Klymak), with a swarm of EM-APEX floats (Sanford, Shcherbina), and a flotilla of gliders (Shearmann), as well as with satellite remote sensing (Harcourt) and ultimately with numerical models (Mahedevan, McWilliams, Molemaker, Ozgokmen, Tandon). Members of the DRI field team have also studied fine structure and microstructure with a heavily instrumented AUV (Goodman) and a heavily instrumented towed system (Kunze). Theory will be applied to our observations by all of the DRI PI's and their students and post-docs, but especially by Ferrari, Smith, Thomas, McWilliams.

WORK COMPLETED

This section is lidar specific; refer to Ledwell (WHOI) and Sundermeyer (UMD) reports for a broader scope.

FY 08-10
After the LATMIX kick-off meeting the lidar system modification design effort was initiated. During this period the lidar telescope was redesigned to separate the green and blue return signals and record them simultaneously. The redesign included insertion of a beam-splitting device, insertion of logarithmic amplifiers in the electronic signal path, software changes to control two receivers and software changes to record two waveform channels. Due to Navy project funding shifts, the lidar system was de-installed form the Twin Otter and installed in a Navy P3. The physical install occurred in July of 2010 but due to unforeseen flight certification issues, the lidar system was not cleared for operation until the following spring.

Figure 1 (l) Drawing of telescope redesign to record simultaneous backscatter and fluorescence signals; (c) interior picture of system install on P3, (r) belly window visible, lidar telescope and scanner are located above window, under floor of P3.

FY11

During the spring of 2011, system flight certification, Navy test plan and system de-bug were completed. In June a system shakedown flight and 4 successful dye mapping flights occurred. WHOI participants, E. Terray and C. Sellers, were on-site at Patuxent River to receive the lidar data for preliminary analysis. The field experiment was conducted roughly 465 km (250 nmi) SW of Cape Hatteras, 785 km (425 nmi) from Patuxent River, MD. A summary of the flights is shown in Table 1. For the 3 flights surveying Flourescein dye, roughly 30 passes per flight sampled the dye patch. For the Rhodamine dye flight, no in air observations of lidar dye detection were made, however, preliminary post-process revealed lidar dye detection. Further analysis and processing will be required to generate Rhodamine concentration maps.

A sample of the lidar return signals, blue backscatter and green Flourescein dye fluorescence, are shown in Figure 2. For this strong fluorescence return, absorption of the blue laser signal is evident in the sudden change in amplitude at the depth of the dye patch. A preliminary map of the geo-registered dye returns from a single pass is shown in Figure 3. A still concentrated core is evident and more diffused dye concentrations are shown to the East and West of the core. Extremely weak but still detectable dye returns are not shown in this preliminary map. Decimated data sets of lidar sampling time and location were generated so that in-situ and lidar measurements can be coordinated and compared. Analysis to detect weak dye returns, invert the lidar signal to dye concentration and advect each flight pass's dye hits is an ongoing effort between NAVAIR, WHOI and UMD.

Table 1 Flight Description

Take Off (EST)	On-Station (UTC)	Off Station (UTC)	FLT HRS	Description
02JUN2011 1930	03UN2011 0015	03JUN2011 0145	3.5	Shake-down flight, tested flying tracks, lidar system,
08JUN2011 1930	09JUN2011 0100	09JUN2011 0200	4.2	First Dye Flight, laser doubler crystal failed in flight, no data
09JUN2011 2100	10JUN2011 0230	10JUN2011 0830	9.3	E-W flight pattern over N-S FLR dye streak, 30 passes dye noted
13JUN2011 1930	14JUN2011 0045	14JUN2011 0515	6.1	RHD dye flight
14JUN2011 2015	15JUN2011 0130	15JUN2011 0545	6.1	FLR dye flight, 30 passes dye noted
15JUN2011 1930	16JUN2011 0045	16JUN2011 0415	6.1	24 hr old FLR, new FLR and surface FLR, >30 passes dye noted
17JUN2011 1930	Na	na	3.4	No Data – Thunder storms over the site

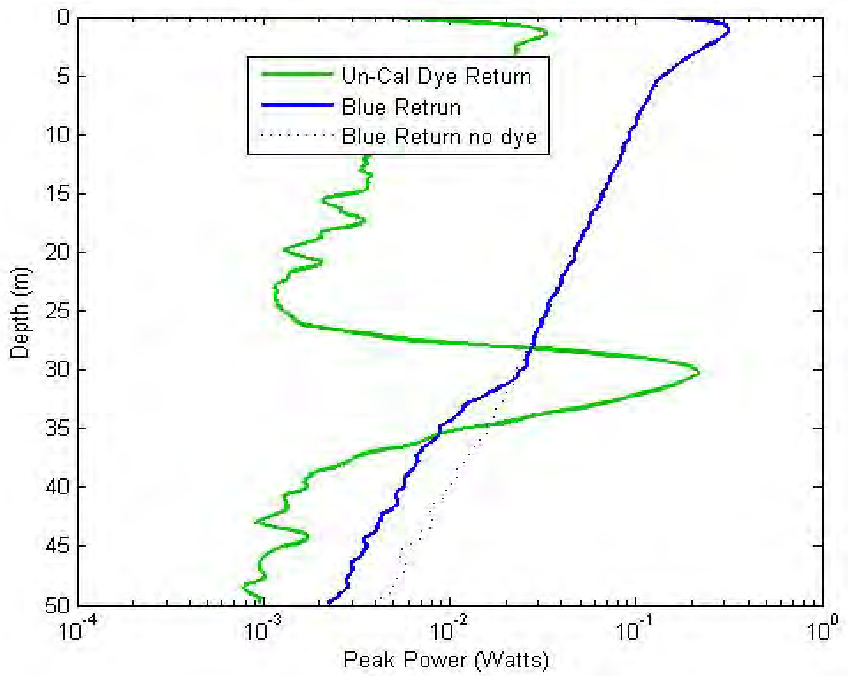

Figure 2 An example of the dye return signal (green) and lidar backscattered return signal (blue), sampling water with (solid) and without dye (dotted).

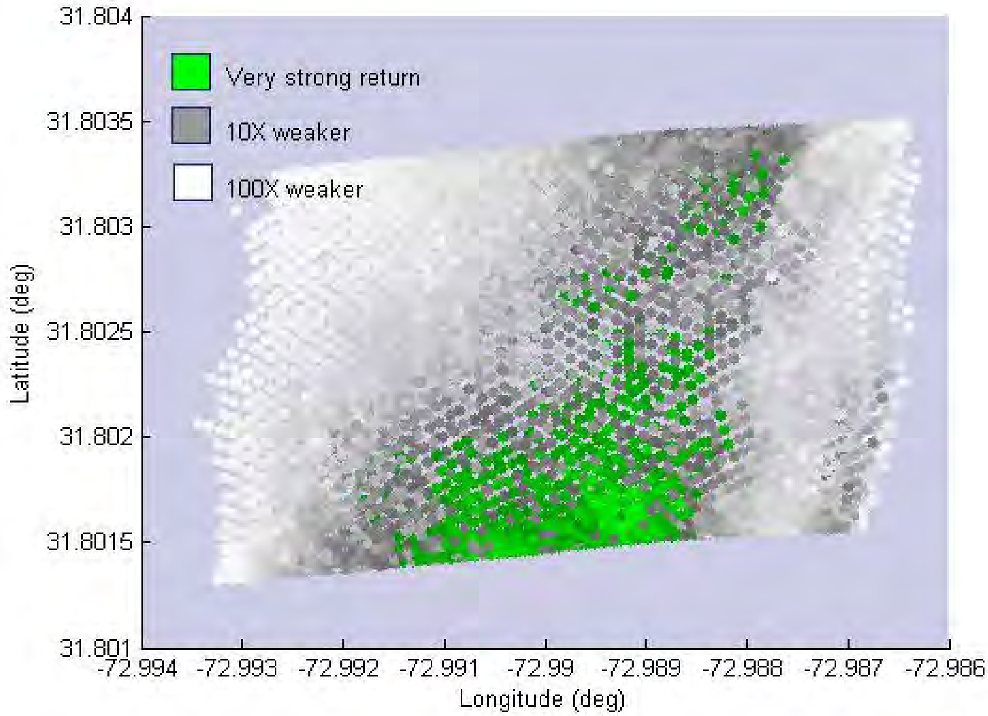

Figure 3 Geo-registered dye returns from a single flight pass, the dye return strength varies from the central core to the edges of the streak by several orders of magnitude, indicating similar dye concentration variations.

RESULTS

To date, analysis pertaining to the understanding of lateral mixing processes in the ocean on scales of 10 m to 10 km is not complete. However, it is clear that the capability to measure processes on the scales of 10 meters in the horizontal and 1 m in the vertical with >3 decades of signal dynamic range for sustained periods of time will play an important role in this analysis.

IMPACT/APPLICATIONS

The results of this investigation will help determine the importance of submesoscale measurements in modeling and understanding of lateral mixing processes in the ocean. Lidar system measurements could provide even finer scale measurements if warranted.

RELATED PROJECTS

None

REFERENCES

Sundermeyer, M. A., E. A. Terray, J. R. Ledwell, A. G. Cunningham, P. E. LaRocque, J. Banic, W. J. Lillycrop, 2007: Three-Dimensional Mapping of Fluorescent Dye Using a Scanning, Depth-Resolving Airborne Lidar. *J. Atmos. Oceanic Technol.*, **24**, 1050–1065.
doi: 10.1175/JTECH2027.1